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THE TOTAL ECLIPSE OF THE SUN,

JANUARY 1, 1889.

REPORT

OF

WASHINGTON UNIVERSITY ECLIPSE PARTY.

St. Louis

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THE TOTAL ECLIPSE OF THE SUN,

JANUARY 1, 1889.

A REPORT OF THE OBSERVATIONS MADE

BY THE

WASHINGTON UNIVERSITY ECLIPSE PARTY,

AT

NORMAN, CALIFORNIA.

Published by The Academy of Science of St. Louis.

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THE TOTAL ECLIPSE OF THE SUN,

JANUARY 1, 1889.

REPORT OF WASHINGTON UNIVERSITY ECLIPSE PARTY.

INTRODUCTION.

THE two total solar eclipses which occurred in the year 1889, the first on January 1, and the second on December 21, were the last of a somewhat rapid succession of important total eclipses. There will not be another until April 16, 1893.

It seemed, therefore, highly desirable that these should be utilized as far as possible to solve some of the problems relating to the solar corona which seem ready for solution at the present time.

The first of these eclipses was visible from the western part of the United States, and, as no appropriation had been made by Congress to enable government astronomers to observe the eclipse, it devolved upon private observatories to make whatever observations were possible. As the Observatory of Washington University was one of the nearest to the path of totality, it seemed proper that special effort should be made by this observatory to observe this eclipse.

The Observatory possesses no photographic equipment nor is its astronomical equipment suited for such work. The expedition was made possible, therefore, only by the kindness of government officials and others in lending instruments, and by the liberality of friends of Washington University in subscribing money for the necessary expenses.

For photographic work I was fortunate enough to obtain from the Navy Department one of the large Dallmyer lenses belonging to the United States Naval Observatory. This instrument was secured at the request of Senator F. M. Cockrell, to whose personal interest in this matter I am indebted in the greatest degree.

An excellent refractor, of four-inches aperture, the property of the Morrison Observatory, was kindly lent by Professor C. W. Pritchett, Director of that observatory.

A second refractor, of three-inches aperture, was lent by the firm of Blattner & Adam of St. Louis.

The plates used in the photographic work were given by the M. A. Seed Dry Plate Co., and were prepared by Mr. Seed from a special emulsion for this work.

The materials for the temporary observatory at Norman, California, were furnished by Senator John Boggs of that state. To Senator Boggs and to Mr. N. D. Rideout, of San Francisco, we are indebted for numerous courtesies and for the most kindly and opportune assistance at the observing station.

The money to defray the expense of the expedition was subscribed by the following gentlemen, to whose public spirit and interest in science the success of the expedition is due.

Mr. Henry Hitchcock.
Col. Geo. E. Leighton.
Mr. Wm. M. Page.
Mr. R. S. Brookings.
Mr. D. S. Holmes.
Dr. Edward Evers.
Judge J. H. Lightner.
Mr. Adolphus Busch.
Mr. Wm. A. Hargadine.
Mr. W. H. Pulsifer.
Mr. Edwards Whitaker.
Mr. David C. Ball.
Mr. E. S. Rowse.
Gov. E. O. Stanard.
Mr. G. W. Simpkins.
Dr. Chas. Luedeking.
Prof. H. A. Wheeler.
Mr. W. A. Stickney.
Mr. John T. Davis.
Mr. Charles Parsons.
Mr. Wm. E. Guy.
Mr. H. W. Eliot.
Dr. John Green.
Mr. J. Clifford Richardson.
Dr. Enno Sander.
Mr. Henry Haarstick.
Mr. M. L. Gray.
Judge Jacob Klein.
Mr. Robert Moore.
Mr. B. B. Graham.
Mr. Chas. Heisler.
Mr. N. O. Nelson.
Mr. R. M. Scruggs.
Mr. Leo Ehrlich.
Mr. S. H. Blewett.

In addition, special recognition is due the following officials of Railway and Transportation Companies without whose kindly co-operation it would not have been possible to undertake the transportation of observers and instruments over such long distances.

Mr. Chas. M. Hays, of the Wabash Railroad.
Mr. S. H. H. Clark and Mr. Geo. C. Smith, of the Missouri Pacific Railway.
Mr. Thos. L. Kimball and Mr. H. L. Korty, of the Union Pacific Railway.
Mr. A. N. Towne, of the Southern Pacific Company.
Mr. John A. Grant, of the Texas & Pacific Railway.
Mr. Geo. M. Pullman, of the Pullman's Palace Car Company.
Mr. L. A. Fuller, of the Pacific Express Company.

For the successful outcome of the expedition I am especially indebted to my associates, Professors Nipher, Engler, and Charroppin and to Señor Valle of the National Observatory of Mexico, who kindly consented to become a member of the party.

We are indebted to Professor Holden, Director of the Lick Observatory, for numerous courtesies, and to Mr. Keeler of the same observatory, who kindly undertook the determination of the geographical co-ordinates of the station after our departure from the state.

H. S. PRITCHETT,
In charge of Washington University Eclipse Party.

REPORT OF PROFESSOR PRITCHETT.

THE Washington University Eclipse Party was made up as follows: —

H. S. PRITCHETT, Director of the Observatory of Washington University.
F. E. NIPHER, Professor of Physics, Washington University.
E. A. ENGLER, Professor of Mathematics and Descriptive Geometry, Washington University.
C. M. CHARROPPIN, S. J., Professor of Astronomy, St. Louis University.

On December 16 the instrumental equipment was completed by the receipt of the photographic equatorial from Washington, kindly forwarded by Captain Phythian, Superintendent of the United States Naval Observatory, as soon as permission for its use could be procured from the Navy Department.

Leaving St. Louis on the evening of December 21, and travelling *via* Denver and Salt Lake City, we reached Sacramento, California, on the morning of December 27.

At Sacramento, I was fortunate enough to meet my friend Professor F. Valle of the National Observatory, Mexico, who had come to California to observe the eclipse and who at my invitation joined our party and contributed in no small degree to our success.

Leaving Sacramento on the morning of December 27, we travelled up the Sacramento Valley, somewhat undecided as to whether it was better to choose Willows or Norman as an observing station. Norman lay exactly in the centre of the path of the shadow cone, while Willows lay some seven miles north of the centre.

A party from the Harvard College Observatory was already established at Willows under the charge of Professor W. H. Pickering. As it was desirable to distribute the photographic parties as much as possible, it was decided to make Norman our station, if proper accommodations could be secured.

Fortunately, we met on the train Senator John Boggs, of the California Senate, to whom I had letters of introduction. Senator Boggs was on his way to Norman, near which place he has a country home. He at once took charge of our party so far as the commissariat was concerned, and, on arrival at Norman, installed us in the

cottage of his friend, Mr. N. D. Rideout, of San Francisco. The cottage was at the time in charge of a Chinese cook, and became our home during our stay in Norman.

The kindness of Senator Boggs and Mr. Rideout in this matter placed us under the greatest obligations. The members of the party, except Señor Valle, were all college professors actively engaged in class work and therefore necessarily detained at home until the last moment; and so short was the time left for preparation, that had we not been so conveniently situated the difficulties of the work would have been greatly increased.

Our instruments, which had been shipped to Willows, were brought down by Professor Engler on the morning of December 28, on a special train kindly supplied by the Southern Pacific Company. Lumber for the temporary observatory, the gift of Senator Boggs, was brought on the same train, and by noon of that day the building had been commenced, and preparations for observing the eclipse went forward with all possible despatch. The succeeding three and a half days were fully crowded with work. The rough observatory was put up, the instruments were set up and adjusted, and numerous experiments were made for photographic purposes. Fortunately Mr. Rideout's cottage seemed to have been built with a special view to the needs of an eclipse station. A dark closet of ample dimensions was already prepared, while a tank, into which water was pumped by wind-mill power, provided a constant flow of good water.

Geographical Position of the Station.

Norman is a very small hamlet situated on the north branch of the Southern Pacific Railroad, about one hundred and thirty miles from San Francisco. It lies in the middle of the broad and level Sacramento Valley, with the Coast Range on the west and the Sierra Nevadas on the east. The railroad for a number of miles runs almost north and points directly at Mount Shasta, which stands at the head of the valley. In fact, so nearly was Mount Shasta in our meridian that its snow-capped cone was used for instrumental adjustment without appreciable error.

The cottage of Mr. Rideout stands about half a mile north of the Railway Station of Norman and on the eastern side of the track, in Quarter Section 15, Township 18 North, Range 3 West of Mount Diabolo Base Meridian. The shed for the telescope was set up directly in front of Mr. Rideout's cottage, and the latitude and longitude of the station were referred to it. Time was obtained from the time signals of the Lick Observatory, and the latitude and longitude of the station were subsequently determined by Mr. Keeler of the Lick Observatory, whom Professor Holden kindly

detailed for this work. Mr. Keeler's report in complete form is given later.

The results of his observations are as follows: —

Latitude Photographic Pier	39° 24′ 58″.8 ± 0″.3
Longitude West of Greenwich	8^h 8^m 45^s.39 ± 0^s.05

Time Observations.

All time records of the expedition were made from the face of Mean Time Chronometer, Dent 2748, except the records of contact observations by Professor Engler, which are from the face of pocket-chronometer Patek-Philippe 4481.

The chronometer had a small rate during the interval over which the observations extend. It was compared as often as possible with the time signals from the Lick Observatory. The resulting corrections are given with respect to Standard Pacific time, which is eight hours slow of Greenwich, and both the observed comparisons and corrections are contained in Table I. The corrections to the Lick Observatory time signals are from the Astronomical Journal, No. 189.

The signals received at Norman came from the Lick Observatory, repeated but once. The armature time is therefore quite small, and as the same armature time is contained in the Longitude results, no account has been taken of it.

Instrumental Equipment.

(a) *Photographic.* The photographic equipment of the party consisted of an equatorial camera having for its objective one of Dallmyer's patent portrait and group lenses, of the size known as No. 8 D.

The lens is the property of the United States Naval Observatory, and was used in the eclipse of 1878 at La Junta, Colorado, by Professor Hall. The constants of the instrument are taken from the report of Professor Harkness, (Washington Observations, 1878, Appendix,) who used an exact duplicate of this instrument at Creston, Wyoming.

This lens has a clear aperture of 6.0 inches, and an equivalent focal length of 37.9 inches. Its tube is cylindrical in form, 7.42 inches in diameter, and made of Russia iron. It is fitted with two series of holders arranged to carry plates 4 by 5 inches, one series being for wet and the other for dry plates. A finder having a clear aperture of 0.7 inch is attached to the camera to enable the operator to bring the image of the sun upon the centre of the plate without the loss of time consequent upon inserting the ground plate, — a matter of great importance during the brief totality of a solar eclipse.

The tube was mounted upon an equatorial stand belonging to one of the five-inch Clark equatorials used in the observations of the transit of Venus. This stand is very firm, has divided circles upon both axes, and is provided with an excellent clock-work.

The instrument was in position by the evening of December 29. It was adjusted closely in equatorial position, and the clock was regulated by Professor Nipher with the greatest care. On the morning of January 1, the clock was in excellent adjustment.

It was found by Professor Harkness, in 1878, that the visual and photographic foci of this lens accurately coincide. The instrument was therefore carefully adjusted to the eye, and the focus thus obtained was used. Practice during the experimental work showed that this adjustment could not be improved.

The plates used in practice were of the same sensitiveness as those used in the photographs of the corona. These plates were very rapid, being Seed's 26, prepared by the M. A. Seed Dry Plate Co. of St. Louis.

It was found extremely difficult to make the tube light-tight for these plates, and a very little experience showed that no method of exposure except an automatic shutter would suffice to protect the plates from fogging.

The largest shutter which could be procured in St. Louis was one worked by the ordinary air bulb and having a clear aperture of 4.5 inches. This shutter was carefully fitted to the tube of the camera, and used in all the observations of the eclipse, thus cutting down the effective aperture from 6 inches to 4.5, but no doubt increasing the sharpness of the picture.

(b) *Telescopic.* The party was provided with two telescopes known as "Telescope A" and "Telescope B."

Telescope A was a four-inch Clark refractor mounted equatorially, and provided with magnifying powers ranging from 50 to 400. It was mounted twenty feet south of the photographic pier. In observing contacts, shade glasses were used having a combination which gave a dirty-white image of the sun.

Telescope B was a refractor of three-inches aperture by a French maker, and had an altitude and azimuth mounting. The instrument was mounted twenty feet north of the photographic pier, and was used by Professor Engler in observing contacts and in making a study of the corona.

The constants to be used in the reduction and discussion of the observations are here collected : —

Latitude Photographic Pier . . . . . 39° 24′ 58″.8
Longitude 8h 8m 45s.39

TABLE I.

CHRONOMETER COMPARISONS AND CORRECTIONS.

Date.	Reading Dent 2748.			Corresponding Time Lick Obs'y Signals.			Correction Lick Obs'y Signals.	Correction Dent 2748 on Pac. Stand. Time.
	h.	*m.*	*s.*	*h.*	*m.*	*s.*		*s.*
1888, Dec. 27	23	59	59.7	0	00	0.0	....	+ 0. 3
" " 28	23	57	53.9	23	58	0.0	....	+ 6. 1
" " 29	23	59	49.5	0	00	0.0	....	+10. 5
" " 31	0	7	42.0	0	08	0.0	+0.35	+18.35
1889, Jan. 1	23	52	35.9	23	53	0.0	−0.18	+23.90
" " 2	23	59	29.2	0	00	0.0	+0.01	+30.81

TABLE II.

INSTRUMENTAL CONSTANTS.

Instrument.	Clear Aperture.	Effective Aperture.	Focal Length.	Mag. Power.
	in.	*in.*	*in.*	
Equatorial Camera	6.0	4.5	37.9	
Telescope A	4.0	4.0	54.0	84
Telescope B	3.0	3.0	....	35

Operations of the Day of Eclipse.

While practice at the station was in progress, a regular programme of work had been mapped out for the day of eclipse.

For the photographic work this programme had been practised over and over again, until the observations could be repeated with machine-like precision.

Professors Nipher and Charroppin had charge of the photographic equatorial. Professor Nipher made the exposures and noted the time; while Professor Charroppin placed the plates in position, pulled the slide, gave Professor Nipher the signal for exposure, recovered the plate and removed the holder, replacing it with another. The work of preparing the plates and loading the plate-holders, as well as the work of development, was in the hands of Professor Charroppin. To his skill as

a photographer is largely due the success of the photographic work. The negatives were developed by him at Norman, on the evening of January 1. His report gives in detail the process of development.

It was decided, after considerable experiment, to expose seven plates with time exposures varying from half a second to thirty seconds.

The time and length of exposure for each plate is given in Table III.

Telescope A was employed by myself in observing contacts, and in a somewhat rapid search for suspicious objects in the immediate vicinity of the sun. A magnifying power of 84 was used.

Señor Valle made naked eye observations of the coronal streamers, using apparatus similar to that employed by Professor Newcomb at Separation, Wyoming, in the eclipse of 1878. A screen consisting of a round disc 14.9 inches in diamter and subtending an angle of 68′ at the eye, was placed at an elevation of 30.9 feet above the ground. The altitude and azimuth of the sun were carefully computed for the moment of central eclipse, and a stake was driven in the ground in such a position that when viewed from the top of the stake the screen would cover the eclipsed sun and the bright inner corona. The height of the stake was 5.5 feet. The distance of the screen from the eye was 62.6 feet, and it would therefore cut off about 17′ of the corona all around the moon. Señor Valle covered his eyes with a heavy dark cloth for some six minutes before the beginning of totality, uncovering them at a signal given by an assistant after totality began. Señor Valle's report gives in detail the result of his observations.

Observations of the Eclipse.

The weather for the four days preceding the eclipse and on the morning of January 1 was of such a character as to give but small hope for clear sky. December 30 was the only clear day of our stay in Norman. During December 31 the sky was almost continually cloudy, with occasional streaks of heavy, black clouds.

The morning of January 1 dawned clear, with light, fleecy clouds in the east. Photographs of clouds were made just before sunrise. By eleven o'clock all details of preparation were completed, and nothing further was to be done except to get the Lick Observatory time signals at noon.

The first contact was due at Norman at $0^h\ 23^m$. By eleven o'clock light clouds had begun to cover the sky; by noon the clouds had so thickened that the sun could scarcely be seen.

The first contact was lost in a heavy bank of clouds, and the disc of the sun

was invisible until some six minutes after the computed time of contact. During the next hour bands of heavy cirrus clouds, separated by spaces of clear sky, swept over the sun from the west.

At $1^h\ 25^m$, the sky around the sun was clear; there was a scarcely perceptible wind from the southwest; the seeing was excellent; and the image of the sun was sharp and distinct. This atmospheric condition held until after totality.

Both contacts were observed with great sharpness. The observed times with explanatory notes are given in Table III.

As my attention was given to the noting of the contact time, I did not see the corona until a very few seconds before the beginning of totality. The phenomenon known as Bailey's Beads was very marked. My first impression on looking at the corona with the eye and through the telescope was its extreme similarity to the corona of 1878 which I observed at Las Animas, Colorado. There were the same divergent filaments at the poles, and the same wing-like appendages on both sides approximately in the ecliptic. The corona did not seem to me so bright nor so extensive as that of 1878. The diffused light over the landscape was quite sufficient to enable one to read the face of the chronometer without difficulty at a distance of several feet. I was particularly struck with the brilliant appearance in the telescope of the filaments at the north and south limbs of the sun. They seemed radial at the poles, but gradually bending over and merging into the equatorial streamers in passing from the pole toward the equator. I could not resist the impression that these filaments pulsated.

Notwithstanding the careful search made for suspicious objects near the sun during the eclipses that have been observed since 1878, — and particularly in the one of long duration observed by Professor Holden's party in the Caroline Islands, in 1883, — it seemed worth while to devote one of our telescopes to this work. I therefore spent the greater part of the 120 seconds of totality in rapidly sweeping over a region extending about $2\frac{1}{2}$ degrees east and west of the sun, and perhaps a little less than a degree north and south of it. In this region there is a $4\frac{1}{2}$ magnitude star, and there are two of the 5th magnitude. All of these objects were picked up. I did not have at the time the maps issued by Professor Davidson, and the $4\frac{1}{2}$ magnitude red star north, following the sun, was not down on the rough chart I was using. This star was picked up and noted as a suspicious object, and its position was approximately found from the diameter of the field of view as $45'$ north and $1\frac{1}{2}^\circ$ following the sun. The object was immediately identified as a well known red star, on consulting a star catalogue. No other object of a suspicious character was encountered.

A few seconds before the ending of totality I again returned to the sun to be ready for observation of third contact. This contact was also observed with sharpness.

The weird effect of the gradually decreasing light upon the landscape as totality drew on seemed to me even more marked than in the eclipse of 1878. At this season of the year thousands of wild geese find a feeding ground in the wheat fields of the Sacramento Valley. They leave their feeding grounds about eight or nine o'clock in the morning and fly off to the neighboring mountains, returning late in the afternoon for an evening meal. Just as the second contact occurred I could hear the screams of large flocks of these birds returning in great haste for their late afternoon feeding. After the sun reappeared they did not return to the hills again but continued to fly about the neighboring fields in a confused manner, apparently under the impression that nature was somehow out of joint.

Contact Observations.

As has been stated, the atmospheric conditions at the time of second and third contact were excellent, and the same remark is true for the fourth contact. On a scale of 5, I would give all three of these observations a weight of 4.

The observed times of contact are given in Table III., where for convenience I have collected all observations of contact. The column O — C contains the resulting corrections to the computed values of the contact times as deduced from the data of the American Ephemeris.

TABLE III.

CONTACT OBSERVATIONS.

Contact.	Observer.	Weight.	Observed Time.			Correction to Time-Piece.	Pacific Standard Time.			O – C
			h.	*m.*	*s.*	*s.*	*h.*	*m.*	*s.*	*s.*
II.	Pritchett	4	1	47	25.0	+24.4	1	47	49.4	+3.2
II.	Engler		1	47	58.5	− 7.2	1	47	51.3	+5.1
III.	Pritchett	4	1	49	25.0	+24.4	1	49	49.4	+5.8
IV.	Pritchett	4	3	7	28.8	+24.7	3	7	53.5	+5.1
IV.	Engler		3	7	57.2	− 7.3	3	7	49.9	+1.5

Exposure of Plates.

It was decided to use seven plates with exposures varying from the quickest possible to about thirty seconds. Table IV., which follows, gives the necessary data concerning the times of beginning and end of exposures.

The number of the negative was scratched on the plate before being put into the holder, and the corresponding number was marked in pencil on the holder itself. Just before the beginning of totality the plates were brought out to the temporary observatory, and placed in the proper order on a shelf prepared for that purpose. The lengths of exposure were determined from the beats of the driving clock.

TABLE IV.

Number of Negative.	Beginning of Exposure, Pacific Standard Time.			End of Exposure, Pacific Standard Time.			Length of Exposure.
	h.	*m.*	*s.*	*h.*	*m.*	*s.*	*s.*
1	1	47	52				0.5
2	1	48	00	1	48	3	3.0
3	1	48	09	1	48	15	6.4
4	1	48	22	1	48	40	18.4
5	1	48	46	1	49	14	27.8
6	1	49	21	1	49	34	13.4
7	1	49	40	Lost by sticking of the slide.			

The negatives were developed at Norman immediately after the eclipse, in the order 3, 2, 6, 4, 5, 1.

To provide for the proper orientation of the plates, the inclination to the horizon of the side of the plate-holder marked "a" was read by a clinometer a number of times immediately preceding and following the time of totality. It was assumed that the edges of the plates were parallel to the sides of the plate-holders. This was the only method available at the time, and probably gives the position of the plate within half a degree. The readings of the clinometer and the corresponding inclinations of the upper northwest edge "a" of the plate to the horizon are given below. The clinometer was divided to half degrees, and the readings were taken at exact degrees.

Date.	Pacific Standard Time.			Inclination of Edge "a" to Horizon.
	h.	*m.*	*s.*	°
Jan. 1, 1889	1	1	25	25.0
" "	1	20	0	29.0
" "	1	34	40	32.0
" "	1	50	55	35.0
" "	1	54	10	36.0
" "	2	5	55	38.0

From these readings we have the following values of the inclination of edge "a" for each negative.

Number of Negative.	Inclination of Edge to Horizon.	Number of Negative.	Inclination of Edge to Horizon.
	°		°
1	34.5	4	34.6
2	34.5	5	34.6
3	34.6	6	34.7

The readings of the clinometer were found to be subject to a correction of $-0°.3$ on account of index error and eccentricity.

From these data it is possible to orient the plates with respect to any assumed line.

In reproducing the negatives it was found convenient to adjust them with respect to the horizon before printing, so that the lower edge of each picture represents accurately a horizontal line, the inclination of which to a parallel of declination was $20° 12'.3$. This method of printing was used in the case of the four negatives which are reproduced, as well as in the case of the REPRODUCTION FROM ALL THE NEGATIVES. This device avoids the necessity of putting extra lines on the page in order to show the position of a reference plane. From this datum the position of the equator and ecliptic and of the sun's axis can be at once indicated.

THE NEGATIVES.

The six negatives obtained are all of excellent definition, though some of them are thin.

The negatives of short exposure are characterized by sharp definition of the polar filaments, while those of longer exposures show the streamers of the outer corona.

Artotypes of negatives 1, 2, 3, and 5 appear at the end of this publication. A short statement descriptive of each is placed on the page facing it.

In the negatives, the diameter of the sun's disc is 0.38 inch; in the artotypes, this dimension is enlarged to 1.00 inch. The artotypes were made by Edward Bierstadt, of New York.

Negatives No. 4 and No. 6 were not reproduced, for the reason that they contained no details not to be found in the others.

Following the four reprints of negatives is given an artotype reprint of a drawing which is essentially a combination of all the negatives. It is manifestly impossible to obtain on one negative a complete picture of both the outer and inner corona,

since a negative exposed for a sufficiently long time to receive an impression from the faint coronal streamers will be over exposed for the brighter inner corona.

In this reproduction from all the negatives no feature has been included which was not certainly shown on the ngeatives, and this reproduction may be taken as the definitive result obtained at this station for the form of the corona. This reproduction has been made with great care, and the result possesses substantially the accuracy of the original negatives. The method of reproduction is explained by Professor Engler in his report.

The results to be derived from careful reproductions of the sun's corona come largely from a comparison of such pictures with the representations of the corona at other times. It is believed that the negatives of the corona whose reproduction has been attempted in this publication will thus be of increasing value, as they may be compared with similar negatives of the corona taken on future occasions, and that enough such evidence may be finally gathered to give a fairly satisfactory answer to some, at least, of the many unsolved problems respecting the nature and maintenance of the corona.

An examination of the negatives at once brings out evidence of the great complexity of arrangement of the coronal matter. This very complexity of lines and coronal streamers greatly increases the difficulty of presenting a mathematical discussion of the physical problem.

The polar filaments form a marked feature of the negatives of short exposure. These are arranged in straight lines, but are not radial. Between the filaments there is in many cases almost an entire absence of coronal matter down to within a tenth of a diameter from the sun's disc. Comparing our negatives with a copy of a negative taken by the Lick Observatory party at Bartlett Springs, I find the number of filaments and the spaces between to correspond accurately, showing the actual arrangement of the coronal matter in this form.

The testimony of the negatives of the corona of Jan. 1, 1889, is to confirm the opinion already held that there is a characteristic form of the corona corresponding to periods of sun-spot maxima and minima.

H. S. PRITCHETT.

WASHINGTON UNIVERSITY,
St. Louis, Mo.

REPORT OF PROFESSOR NIPHER.

In the assignment of the work of the Eclipse Party, I was requested by Mr. Pritchett, the director of the party, to take charge of the equatorial camera furnished to him by the U. S. Naval Observatory. The instrument reached St. Louis at the time when we had intended to start for the Pacific coast. It was set up at the Washington University, and was found to require some modification before the very sensitive plates which we were to use could be safely exposed. There were only seven plate-holders with the instrument, and it was impossible to increase the number from lack of time. It was found that the central tie-rod in the stand had been forgotten, and another was made. It was also necessary to supply the instrument with a shutter. The largest one that could be secured had an opening of 4.5 inches, which probably gave better definition than a larger one would have done. The instrument was set up at Norman on the morning of December 28, the meridian being secured by sighting on Mt. Shasta, which was directly north of the station a distance of 140 miles.

The cool nights and damp atmosphere seemed to affect the clock somewhat, and it was cleaned. At the same time it was found that one of the clock-spring tension-straps was on the point of breaking. The instrument was finally put in perfect order, and was adjusted so that it would hold the solar image without appreciable motion for an hour.

On December 30 and 31 the observers drilled themselves in the routine of the observations.

With the limited time and corps of observers, the following plan of observation was adopted.

The shutter was sprung by myself, the interval of exposure being determined by counting the beats of the driving clock. The pendulum beat 140 times to the minute. The first plate was exposed during as brief a time as was possible with the shutter used. The remaining negatives were to have exposures as indicated in the following table.

No. of Plate.	Beats.	Seconds.	No. of Plate.	Beats.	Seconds.
1	....	.....	5	65	28.0
2	7	3.0	6	32	13.7
3	15	6.5	7	11	4.7
4	43	18.4			

When the shutter closed after each exposure, I called "change," and Professor Charroppin replaced the slide by the one to be next exposed, announcing the time for the beginning of the next exposure by the word "ready."

During the rehearsal of our programme on December 30 and 31 our operations were all timed by Mr. Engler. The means of all the results are given in the table below. The first interval gives the mean time required to replace plate one by plate two, and the numbers following represent the time for succeeding changes.

	Plate 1.		Plate 2.		Plate 3.		Plate 4.		Plate 5.		Plate 6.		Plate 7.
Exposure	0.3		3.0		6.4		18.4		27.8		13.4		4.5
Interval		6.5		6.4		7.0		6.0		5.8		5.3	

The individual intervals differed from these means by about half a second.

During the eclipse a card giving the duration of the exposures in beats was before me. A copy was also placed in the hands of a visitor at the station, who was directed to remind me after each exposure of the duration of the next exposure.

The entire programme was carried out with the same regularity that had been attained in the preparatory drills, with the exception of the failure on the final plate.

The first plate was exposed, as nearly as I could estimate, at three seconds after Mr. Pritchett called time on second contact.

The time of beginning and ending of each exposure by Dent 2748 was therefore about as follows:—

Plate.	Beginning.			Ending.			Exposure.
	h.	*m.*	*s.*	*h.*	*m.*	*s.*	*s.*
1	1	47	28.0	1	47	28.3	0.3
2	1	47	34.8	1	47	37.8	3.0
3	1	47	44.2	1	47	50.6	6.4
4	1	47	57.7	1	48	16.1	18.4
5	1	48	22.1	1	48	49.9	27.8
6	1	48	56.0	1	49	9.4	13.4
7	1	48	15.1	.....			....

The correction of Dent on Pacific time is +24.5 seconds.

My first impression of the corona was that of disappointment. The eclipse of 1869 made a much more vivid impression upon me, and I was surprised to find the corona so small. We had lighted lanterns in order to provide against a possibility of being unable to see the chronometer hands, but they were wholly unnecessary. The changing hues of the landscape during an eclipse are noticeable chiefly as the accompaniment of a grand phenomenon rarely seen, and because the changes occur so rapidly. Similar effects accompany violent storms. They are continually occurring without being perceived, the changes occurring so gradually that they are unnoticed because of our inability to make comparisons at widely separate times.

The Theory of the Solar Corona.

The writer has been unable to formulate any theory of the corona which could survive his own criticism. There have been several explanations of the phenomena of the corona, some of which have commendable features, and all of which are open to grave objections.

A mathematical theory of the corona, by Professor Frank H. Bigelow, published by the Smithsonian Institution, is perhaps the most ambitious of these attempts, and a few comments upon it may not be inappropriate here. Mr. Bigelow lays down the basis upon which his theory rests in the following words: —

> "We propose to treat this subject by the theory of spherical harmonics, on the supposition that we see a phenomenon similar to that of free electricity, the rays being lines of force, and the coronal matter being discharged from the body of the sun, or arranged and controlled by these forces."

One would suppose that a free electrification of the sun would result in a system of radial lines of force. Mr. Bigelow proceeds to discuss the matter on the assumption that the electrification is distributed over the surface according to the law of cosines. The electrification is assumed to be zero at the equator, and the density of the charges on the two hemispheres varies as the cosine of the latitude.

Such a distribution would result from the placing of a sphere in an external electrical field of uniform strength, the lines of which are parallel to the polar diameter.

Let φ = strength of the external field.

a = the solar radius.

ω = the angle of co-latitude.

R = the radial distance to any point in space, the position of the point being

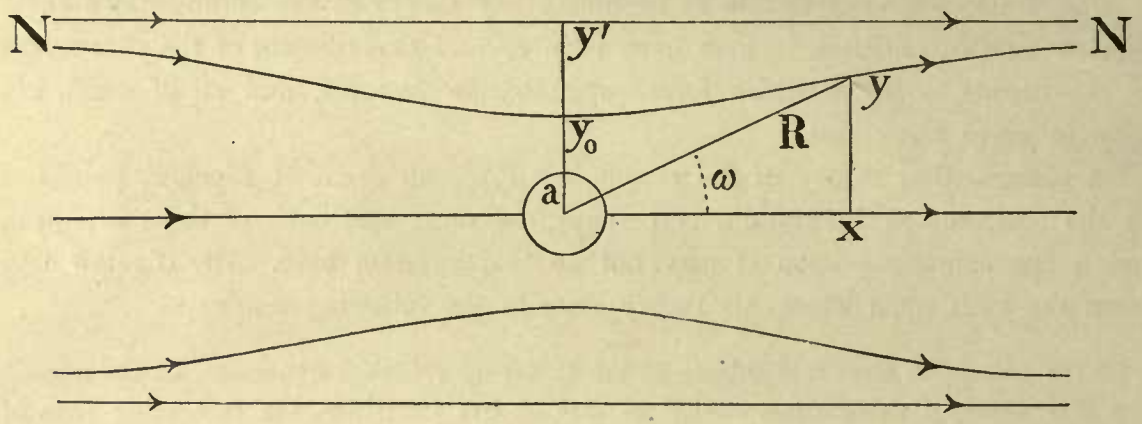
determined by R and ω; then the force at that point due to the induced charges on the sun would be

$$F = \frac{\varphi a^3}{R^3}(3\cos^2\omega + 1)^{\frac{1}{2}}$$

The total force would be due to the force F, and to the force of the inducing field. The equation of the resultant line of force of the order N through the point is

$$N = \frac{2\pi\varphi a^3}{R^3}(3\cos^2\omega + 1)^{\frac{1}{2}}(1 - \cos\omega) + \varphi\pi R^2\sin^2\omega$$

The form of this line is shown in the accompanying figure. It is conchoidal in appearance, and when R is large the line approaches the position which it would assume throughout, were the disturbing effect of the sphere removed.



For a point on this line of force at an infinite distance from the sun

$$R\sin\omega = y'$$

where y' is the perpendicular distance from the centre of the sun to the asymptote of the line of force. The equation of the line of force becomes

$$N = \pi\varphi y'^2$$

x being indeterminate.

If

$$\omega = 90°, \qquad R\sin\omega = y_0 = R$$

where y_0 is the distance from the centre of the sun to the vertex of the conchoidal line. The equation of the line becomes

$$N = \frac{2\pi\varphi a^3}{y_0} + \pi\varphi y_0^2.$$

CORRECTION.

The Total Eclipse of the Sun January 1, 1889.
Report by the Washington University Eclipse Party.

Page 22 line 6 from top should read

$$N = \frac{2\pi\varphi\alpha^3}{R}\sin^2\omega + \varphi\pi R^2\sin^2\omega$$

F. E. NIPHER.

$\sqrt{27}$

it does not.

If $n^3 = \sqrt{27}$ or $n = \sqrt{3}$

the line touches the sphere at its equator.

Nothing can be more evident than the conclusion that these lines are in form wholly unlike the coronal filaments. The equations of Mr. Bigelow are formed on the assumption that a permanent difference of electrical potential can be maintained on the opposite polar hemispheres. A distribution over the sun like that assumed by him, if due to the action of an inducing field, would produce constant potential over and within the sun, and the lines of force would differ entirely from those of his drawing, as has been already shown.

The physical conditions involved in Bigelow's hypothesis are similar to those which we have in a sphere cut from a crystal of tourmaline, when its temperature is different from that of surrounding space.

Knowing what we do of the physical properties of tourmaline, and of the physical conditions on the sun, this assumption seems to be a most extraordinary one. A fair coincidence of the theory with the facts would however justify the provisional statement of the theory, since we cannot be said to know very much about the causes for the behavior of tourmaline.

Later in his paper, under the heading "Terrestrial Magnetism," Mr. Bigelow says: —

"In treating the problem of the earth's magnetism, it has generally been supposed that the forces of induction from the sun to the earth are in straight lines, following the vector joining these bodies. We now see that the earth lies in a magnetic field, uniform by reason of its distance from the sun, the lines of force being directed nearly perpendicular to the

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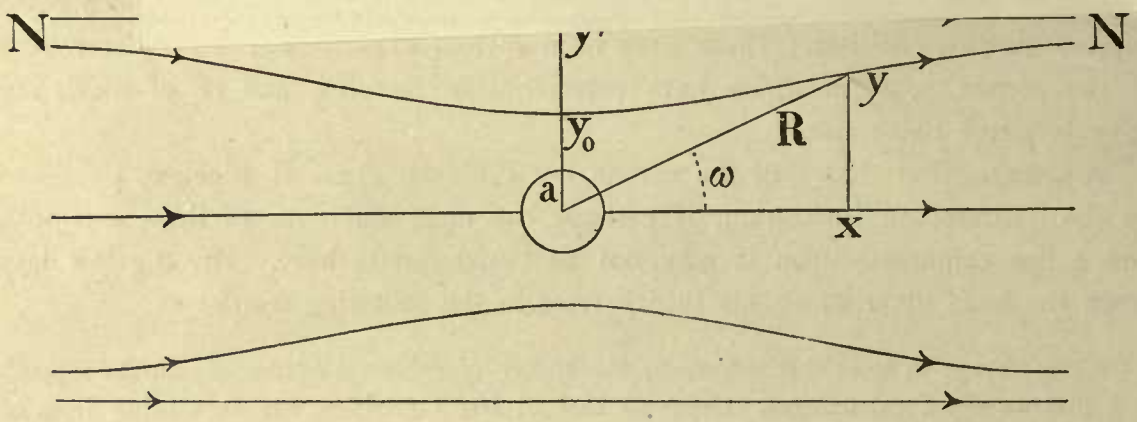

For a point on this line of force at an infinite distance from the sun

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$$N = \pi \varphi y'^2$$

x being indeterminate.

If

$$\omega = 90°, \qquad R \sin \omega = y_0 = R$$

where y_0 is the distance from the centre of the sun to the vertex of the conchoidal line. The equation of the line becomes

$$N = \frac{2 \pi \varphi a^2}{y_0} + \pi \varphi y_0^2.$$

Equating these values of N

$$y_0^3 - y'^2 y_0 + 2 a^3 = 0$$

If

$$y' = n a$$

$$y_0^3 - n^2 a^2 y_0 + 2 a^3 = 0$$

In the solution of this equation, if

$$\frac{1}{a^3}\left(\frac{n^2 a^2}{3}\right)^{\frac{3}{2}} < 1 \text{ or } \frac{n^3}{\sqrt{27}} < 1$$

the line cuts the surface of the sphere ; while if

$$\frac{1}{a^3}\left(\frac{n^2 a^2}{3}\right)^{\frac{3}{2}} > 1 \text{ or } \frac{n^3}{\sqrt{27}} > 1$$

it does not.

If $$n^3 = \sqrt{27} \text{ or } n = \sqrt{3}$$

the line touches the sphere at its equator.

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Later in his paper, under the heading "Terrestrial Magnetism," Mr. Bigelow says: —

"In treating the problem of the earth's magnetism, it has generally been supposed that the forces of induction from the sun to the earth are in straight lines, following the vector joining these bodies. We now see that the earth lies in a magnetic field, uniform by reason of its distance from the sun, the lines of force being directed nearly perpendicular to the

earth's orbit, instead of parallel to it, and of low potential, as the formula shows that the earth lies near the plane of the equator of the corona. . . . If it should appear that the angle is considerable between the plane of coronal equator and the ecliptic, even supposing the corona does not oscillate, yet the earth in its orbit must be passing through fields variable in potential and direction, which will condition some of the periodic changes of the terrestrial magnetism. Knowing the potential of the earth's magnetism and its variations, the data ought to be accessible for obtaining the solar constant of maximum superficial density of electricity, and thus give a clew to the forces acting within the sun."

This passage appears to give some color to the suspicion that Mr. Bigelow is not careful enough in distinguishing between the properties of an electrical and a magnetic field.

The general resemblance of the polar filaments of the corona to magnetic lines of force, has been frequently observed and remarked. The evident and apparently insurmountable difficulty with this view is that at such temperatures as exist on the sun, it is impossible to suppose that any magnetic properties can exist. At a cherry-red heat iron and steel not only lose their magnetism, but cease to be attracted by a magnet. Quantitative considerations seem to forbid the theory of electrical convection as a cause of the sun's magnetism, to say nothing of the complex motions which must be assumed in order to account for the corona. An electrically polarized sun might repel electrified particles, as Mr. Bigelow assumes; but a magnetically polarized sun would hardly repel the magnetically polarized particles which are supposed to compose the filaments.

A physical theory of the corona which requires us to assume conditions which are so difficult to reconcile with our prior experience, ought to have a strong basis of some kind.

With respect to the confirmation of the theory which is afforded by Mr. Bigelow's measurements on Holden's drawing of the corona, and on the Harvard photographs, it does not seem conclusive, to say the least. Some filaments agree fairly well with the theory, and some do not. Mr. Bigelow's candid statement that "the necessity is obvious of rejecting freely such lines of force as are not natural, and the difficulty of obtaining true lines of force is at present great," tends to increase our confidence in him, but does not furnish strong support of his theory. Still Mr. Bigelow becomes so much impressed with it, that he is finally moved to commend the fidelity of Holden's drawing, because it does show some filaments which agree fairly well with the theory.

A study of Holden's drawing shows how freely lines have been rejected which do not agree with the theory, and shows that the coronal structure is so complex

in its character as to furnish, as a whole, a very slender basis for Mr. Bigelow's theory. In fact Holden's drawing seems to agree more completely with the hypothesis that the coronal structure is radial, and that the seeming divergence therefrom is the effect of local disturbance and perspective.

Certainly it would seem that matter ejected from the sun by electrical repulsion should still be subject to gravitation. If the behavior of the ejected matter is wholly explained by the electrical action of an electrically polarized sun, without taking gravitation into account, it is a very unexpected result.

The polar filaments, as shown on the negatives, are so short, making it so difficult to determine their curvature, and show so much of irregularity, that there are doubtless many equations which would be as completely satisfied as those given by Mr. Bigelow.

[1]In recent papers read before the Indianapolis meeting of the American Association for the Advancement of Science, Mr. Bigelow has assumed that the coronal filaments are magnetic lines, and he has, from their measured forms on the negative, determined in each case what their real positions in space must be, in order that all may satisfy the theorem of Gauss for tangential intersection. He finds that the lines as thus located intersect the surface in a zone around the pole; none intersect at the pole. This is thought to identify the solar corona with the terrestrial aurora.

The probability that any coronal filament would intersect the sun near, rather than at, the pole may of course be assumed.

If we consider the shortness of the filaments, and the fact that only three or four points on each of them can be determined, it does not seem that very much can be concluded for such a result. Mr. Bigelow is however now engaged in determining whether the daily and annual changes in the earth's magnetism may not be due to its motions in such a field as he assumes for the sun. This is a plan of attack which promises definite results, and is of the very highest interest. The evident possibility of dealing with the secular variation in the same way, in case the daily and annual changes can be thus accounted for, makes the discussion one of profound importance.

FRANCIS E. NIPHER.

WASHINGTON UNIVERSITY,
St. Louis. Mo.

[1] Added Dec. 6, 1890.

REPORT OF PROFESSOR ENGLER.

At the request of the Director of the Eclipse Party, I devoted my attention to observing the contacts, to making a drawing of the corona from a study through the telescope, and to securing as many other drawings as possible from volunteer observers who viewed the eclipse with the naked eye.

The telescope I used was a French instrument of three-inches aperture with an altitude and azimuth mounting. For the observations I used a magnifying power of 35, and a combination of shade glasses which produced a light grayish-pink color.

Contacts were observed as follows, by watch Patek-Philippe 4481: —

First contact.	Second contact.	Third contact.	Fourth contact.
	h. *m.* *s*		*h.* *m.* *s.*
Lost in clouds.	1 47 58.5	Not attempted.	3 7 57.2

Both observations of contacts recorded were sharp and distinct; but I think the second should be rated higher than the fourth, because the probability of precision in recognizing the instant of second contact is greater.

Comparison of watch Patek-Philippe 4481 with Dent 2748: —

Date.	Dent 2748.			Patek-Philippe 4481.		
	h.	*m.*	*s.*	*h.*	*m.*	*s.*
1888, Dec. 29	1	30	2.0	1	30	0.5
" " 29	20	23	4.0	20	23	10.4
" " 30	20	51	53.0	20	52	10.0
" " 30	23	30	38.0	23	30	55.8
" " 31	23	24	40.0	23	25	9.0
1889, Jan. 1	0	11	30.0	0	12	0.2
" " 1	1	28	24.0	1	28	55.2
" " 1	2	8	32.0	2	9	4.0
" " 1	3	0	18.0	3	0	50.0

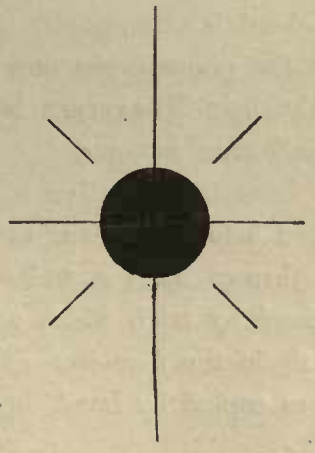
As second contact was approaching, Bailey's Beads were distinctly seen for some seconds.

At the instant of second contact, when the bright image of the corona flashed out from the disc of the moon, the sense of the utter inadequacy of any drawing, however well done, to represent the scene almost paralyzed effort, and the consciousness that there were but one hundred seconds in which to study the corona made me decide instantly to use none of this time for drawing.

About the first ten seconds of totality were employed in making a naked eye study of the corona, and in jotting down its general position and dimensions with reference to the disc of the moon. The rest of the time of totality was employed in making a study of the structure of the corona through the telescope; for this reason the observation of the time of third contact was not attempted.

No nuclei were apparent in any part of the corona; filaments were very decided. The streamers extended along the ecliptic, and were plainly visible in the telescope for five or six diameters of the moon. At the poles they extended in straight lines, convergent but not radial. There was light enough during totality to enable me easily to read the face of the watch, and to jot down my notes. The color of the corona was unlike anything I have ever seen; such descriptive words as silvery, silver-gray, lustrous, luminous, are suggestive to one who has seen the corona, but they are neither precise nor adequate. I know of no way of describing it.

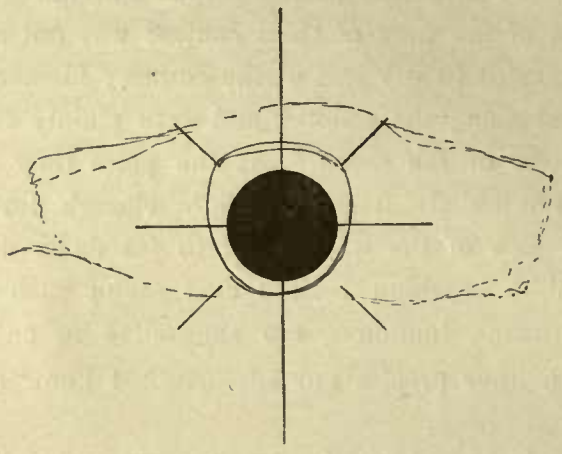
To facilitate the work of making the drawings, large blanks had been prepared containing a black disc, one inch in diameter, to indicate the moon, and lines to assist in plotting positions as shown in reduced size in the accompanying diagram.



These blanks were distributed to a number of persons who consented to make naked eye drawings of the corona; and I used one of them myself, during the two minutes immediately following totality, in making a pencil drawing of the corona

from my study of it through the telescope; the plate bearing my name is a reproduction by the photo-engraving process of this drawing.[1]

A comparison with the negatives shows that none of the drawings of the volunteer observers, although made by persons of at least average intelligence, — there were bankers, lawyers, merchants, and school-teachers among them, — are to be relied upon for even general information concerning the corona, such as its outlines and its dimensions relative to the disc of the moon. The accompanying diagram fairly reproduces one of these drawings.



From this experience I do not hesitate to say that no confidence whatever is to be placed in drawings of the corona made by inexperienced amateurs; such drawings are valuable only in showing the necessity of training both eye and hand before any work of this kind is attempted. At best a drawing is of very little value in comparison with the photographs now easily obtainable.

The Reproduction from All the Negatives is an artotype[2] reduction of a crayon drawing made in the following manner.

An enlarged positive made from the negative which showed the greatest extension of the corona was placed before the lens of an ordinary stereopticon, and the image thus produced was thrown upon a white wall. The lantern was then placed in the position, determined by trial, which gave the best definition to the image on the wall, and this made the diameter of the black disc of the moon about one foot. This image was copied by hand, in crayon, with very great care,

[1] The pen-and-ink copies of the pencil drawings, from which the photo-engravings accompanying this report and that of Señor Valle were made, were drawn by Mr. W. A. Griffith, and are faithful reproductions of the originals.

[2] Larger artotype reproductions of the same drawing, suitable for framing, can be obtained on application to the Observatory of Washington University, St. Louis, Mo., U. S. A.

by Mr. Frederick W. Lippelt, — a most conscientious draughtsman, whose skill in crayon work could hardly be surpassed. The negatives were then in turn studied under a magnifying glass, and every detail of the corona which could be discovered in them was added to the crayon drawing. All of this work was subjected repeatedly to the criticism of the different members of the Eclipse Party, and when completed was artotyped by Edward Bierstadt of New York, with the result as seen in the plate, which is a very faithful reproduction of the crayon drawing. Thus it will be seen that this plate does not represent the corona as seen with the naked eye, nor as shown on any one of the negatives, but is a combination of all that could be found on all of the negatives.

EDMUND A. ENGLER.

WASHINGTON UNIVERSITY,
St. Louis, Mo.

REPORT OF PROFESSOR CHARROPPIN.

THE task assigned to me at Norman, California, was to secure seven photographs of the corona during the two minutes of totality. We had but seven plate-holders; otherwise we could have easily obtained nine negatives of the corona. The photographic plates used on the occasion were Seed's 26, a special emulsion having been made for the Eclipse Party. The instrument was mounted on the morning of December 28. The adjustment of the objective was fully tested. Every day photographs of the sun were secured with a very small diaphragm. Two of these negatives had the disc of the sun surrounded by a halo which resembled somewhat the corona of the eclipse of 1871, as drawn by Foenander. This ghost of a corona was no doubt the effect of some atmospheric disturbance. Another negative of the sun, through a cloud, gave a beautiful effect when enlarged on a screen by means of the oxy-hydrogen light. Venus and the crescent moon were also photographed with excellent results.

The disc of the sun appeared very small on our 4×5 plates, the diameter of the sun measuring only three eighths of an inch. In our experimental work on the sun, three different developers were successively used; namely, the pyrogallic and the sal-soda; the oxalate and iron developer; and the hydroquinone. All three gave good results. To develop the negatives of the corona, the preference was given to the pyrogallic acid developer, it being more manageable in case of over-exposure.

On the morning of January 1, all our preparations were completed. The sensitive plates were placed in their carriers and well sealed.

Four objects requiring different exposures were to be secured, — namely, the chromosphere, the protuberances, the inner corona, and the outer corona. It was evident that the inner corona, which is comparatively very bright, and the protuberances, which abound in actinic rays, demanded very short exposures. We determined to attempt these with an instantaneous and with a three-second exposure. For the chromosphere and fuller details of both the corona and the polar filaments, I allowed two exposures of five and seven seconds respectively.

To secure the full length of the fading streamers of the outer corona, it was evident that long exposures were required, even at the risk of blurring the inner corona and polar filaments. The three remaining plates were marked thirteen, eighteen, and twenty-eight seconds. To avoid all possibility of the slightest fog, the sensitive plates were placed in their kits, in perfect darkness, and finally sealed by the light of a dim ruby lantern.

About fifteen minutes before the second contact, the clouds opened and showed us the moon encroaching rapidly on the sun. Venus, scarcely dimmed by the fading rays of the obscured sun, shone brightly in a clear sky.

Immediately after the second contact was called, an almost instantaneous view was taken, followed by the exposures three, six, eighteen, twenty-eight, thirteen, and five seconds. The last negative was lost; the string of the slide being entangled, only half of the plate was exposed. The negatives were developed immediately after the eclipse. Judging from the light of the corona, and knowing well the sensitiveness of our plates, I concluded five seconds to be about the proper exposure; but that plate was lost on account of the fatal string already mentioned. Having prepared a fresh developer of pyrogallic acid, sodium carbonate, and sodium sulphite, I began to develop the six-second exposure; I soon found the plate to be over-timed. A solution of ammonium bromide was at hand, and twenty minims began the work of retardation. Two minutes later, forty more minims were added. The negatives developed slowly, but beautifully. Potassium bromide is the common restrainer among photographers; but on the present occasion I preferred the ammonium bromide, as its action is less violent and can be kept more easily under control. The first cliché developed was a success. It did not show the full extent of the coronal streamers, but the polar filaments were well defined. The negative was lacking in density for printing purposes; but this very defect gave it its greatest value. It brought out the prominences admirably; six of the largest ones could be seen with the unaided eye. The protuberances, unless very prominent and high, being in the glare of the inner corona, would be lost in a well timed negative, possessing proper density. An over-exposed plate is apt to give a flat picture, the details in the shadows wanting contrast. This peculiarity of the sensitive plate gave us the tiniest prominences, many of which were not to be found on the well timed negatives. This experiment also proved that the protuberances contained more actinic rays than the corona, their impression being darker on the negative. Judging simply from their red color one is apt to come to a different conclusion.

The plate next developed was the three-second exposure. The image appeared slowly; increasing gradually in strength without any extra manipulation. The extreme details of the outer corona were lost; but the negative was evidently well timed, and possessed excellent printing qualities. Very few protuberances were secured; but this experiment gave a clew, for future eclipses, to a full time exposure of a Seed's 26 with a Dallmyer lens. The correct exposure I should judge to be between three and four seconds. To calculate beforehand a proper exposure, other factors of course are not to be neglected, — such as the altitude of the sun, the length of totality, the condition of the atmosphere, etc.

With this newly acquired knowledge of proper exposure, I stood before three very sensitive plates which had been exposed to the coronal rays for thirteen, eighteen, and twenty-eight seconds respectively. I thought of soaking them first in a dilute solution of potassium bromide, which is a powerful restrainer; but then I might defeat the very end for which the long exposures were made, — namely, to obtain the full extent of the streamers. I made a new developer of pyro, full strength, adding two drams of a solution of ammonium bromide containing thirty-two grains of NH_4Br to the ounce of H_2O. The development was extremely slow; and I soon perceived that more NH_4Br would be required. Another quarter of an ounce of the solution was added, and the thirteen-second exposure was saved with a slight fog.

A new developer with an ounce of the solution containing thirty-two grains of NH_4Br developed the eighteen-second exposure without fog, giving the full details of the long western streamers. By an excess of ammonium bromide the twenty-eight-second exposure was saved, and proved to be a valuable negative, showing a remarkable extension of the outer corona and cosmic matter around the polar filaments. This negative gave fuller details of the outer corona than any other, showing the streamers over-lapping each other.

Finally, the instantaneous plate was placed in a dilute developer and treated as an under-timed plate. It gave a very clear negative of proper density; the inner corona was well defined, and the polar filaments showed much better than in the other negatives; the outer corona, as expected, was sacrificed.

C. M. CHARROPPIN, S. J.

St. Louis University,
St. Louis, Mo.

REPORT OF SEÑOR VALLE.

Enviado por el Sr. Ingeniero Angel Anguiano, Director del Observatorio Astronómico Nacional Mexicano de Tacubaya, á los Estados Unidos del Norte, con objeto de estudiar los métodos de observación y los instrumentos, que con motivo del eclipse total de Sol del 1° de Enero de 1889, los astrónomos empleasen, me dirigía yo á Willows, Cal., para visitar la estación astronómica dirigida por el Profesor W. H. Pickering, del Observatorio de la Universidad de Harvard, en Cambridge, Mass., cuando, en la ciudad de Sacramento, tuve la fortuna de encontrar á mi buen amigo el Sr. Profesor H. S. Pritchett de la Universidad de Washington, en S. Louis, Mo., quien en compañía de los Profesores Engler, Nipher, y Charroppin, se dirigía á la zona de la totalidad para observar el Eclipse.

Invitado por el Profesor Pritchett, para acompañarlos en la observación del Eclipse y aceptado con mucho placer tan fino ofrecimiento, el 30, de Diciembre llegué á Norman, Cal., punto que definitivamente había elegido el Sr. Pritchett para establecer su estación.

Al ofrecer al Sr. Pritchett mis servicios para que los utilizase como lo creyera mas conveniente, me hizo el honor de aceptarlos, encomendándome el exámen, á la simple vista, de la corona exterior, y especialmente el de las ráfagas luminosas que con tanto éxito observó el Profesor Newcomb en el Eclipse del año de 1878, fijando con cuanta exactitud fuere posible la posición y magnitud relativa de ellas.

Siendo estas ráfagas muy tenues, sobre todo en sus extremidades, para que pudiese yo observarlas con éxito, me recomendó dicho Señor, cubriese mi rostro con un género oscuro durante cuatro ó cinco minutos inmediatamente ántes de la totalidad, con el objeto de que mis ojos, estando en completo reposo, pudieran adquirir la mayor sensibilidad posible. Ademas se colocó en la posición conveniente una pantalla circular de cartón de 14.9 inches de diámetro que en el momento del Eclipse debía impedir que mis ojos fuesen heridos por los rayos, relativamente muy brillantes, de la cromósfera y de la corona interior, que sin duda los imposibilitarían para poder distinguir las muy tenues extremidades de las ráfagas.

La pantalla se colocó sobre la extremidad superior de una asta, apoyada sobre una galera que había cerca de la estación astronómica y el punto en que debía yo situarme, se fijó atendiendo á la altura y azimut que tendría el Sol durante la totalidad, para que la pantalla cubriese exactamente el disco lunar la cromósfera y corona interior.

Siguiendo en todo las recomendaciones del Profesor Pritchett, cinco minutos ántes de que la totalidad comenzase ó sea á la $1^h\ 42^m$ P. M. (tiempo medio local), me cubrí la cabeza con un denso lienzo oscuro y así permanecí hasta el momento en que un joven colocado cerca de mí, me dió aviso de que la totalidad había comenzado. Rápidamente me descubrí, pero desgraciadamente al hacerlo, probablemente desvié algo la cabeza, pues una luz viva la de la corona interior hirió mi vista deslumbrándome. Inmediatamente cerré los ojos, permaneciendo así algunos segundos mientras tanto me coloqué en la posición conveniente y en seguida dibujé el croquis núm.° 1, procurando que las ráfagas ó haces luminosas quedasen colocados respecto del disco y líneas de referencia que tenía la hoja en que lo ejecuté, en su posición y magnitud relativas, suponiendo que las lineas representasen la vertical y horizontal que pasaban por el centro del Sol durante la totalidad y el disco, la dimensión aparente de la pantalla que según su distancia á mi ojo y su diámetro fué de 1° 8′.

Examinado el croquis citado se ve que dos haces luminosos emanaban del Sol, próximamente paralelos á la Eclíptica y que en sus extremidades se bifurcaban encorvándose hácia afuera; el brillo disminuía progresivamente y el color de un blanco argentino bellísimo, era semejante al de la corona propiamente dicha.

Las regiones polares del Sol aparecían rodeadas de un anillo luminoso de estructura filamentosa, y los filamentos me parecieron ligeramente curvos hácia afuera.

Las magnitudes aparentes de las ráfagas fueron las siguientes, tomando como unidad el diámetro de la pantalla que abrazaba un ángulo de 1° 8′: la ráfaga N. O. 3.0; la N. E. 1.3; la S. E. 2.9; y la S. O. 3.4 diámetros.

Como probablemente mis ojos perdieron algo de sensibilidad al ser heridos por la luz relativamente intensa, de la corona interior, es muy posible, por no decir seguro, que para otro observador que no hubiese sufrido esta contrariedad, los haces ó ráfagas habrían aparecido mas extensos.

Después del segundo contacto interno y cuando ya el disco solar había aparecido por el borde occidental de la Luna, percibí aun el oriental, rodeado de un anillo coronal bastante brillante, de unos tres minutos de espesor por cinco minutos y medio, hasta que la luz difusa que muy rápidamente iluminó la atmósfera lo ofuscó completamente.

El croquis ó dibujo marcado con el número 2 fué ejecutado poco después del Eclipse, sirviéndome de base el número 1 para la posición y dimensiones de las ráfagas, y completando de memoria los detalles que durante la totalidad no tuve tiempo de fijar.

Antes de concluir debo manifestar al Sr. Pritchett y sus dignos compañeros mi cordial agradecimiento por las finas atenciones que me prodigaron.

FELIPE VALLE.

TACUBAYA, MEXICO.

POSITION OF NORMAN.

Report of Mr. Keeler.

The instruments used were the Repsold altazimuth (briefly described in Vol. I., Publications of the Lick Observatory), sidereal chronometer Negus 1720, an aneroid barometer, and a thermometer.

The vertical circle of the altazimuth is divided to 4′, and reads by two micrometer microscopes to 2″, or by estimation to 0″.2. Magnifying power used on telescope, 80.

The time observations were made by placing the instrument in the meridian, and using it as a transit, observing by eye and ear over seven wires. The axis was always reversed once in each set. All corrections for instrumental errors were applied; but the observations were not rigorously reduced, the application of the method of least squares not being considered necessary, as probably in no case would it change the value of the chronometer correction by 0ˢ.02. The probable error of a chronometer correction from eight time stars was about 0ˢ.03.

Signals were received from the Lick Observatory on five evenings at 8 o'clock. Three nights only are available for longitude, on account of clouds. These signals were sent automatically by the mean-time clock at Mt. Hamilton, and were compared with the chronometer at Norman by coincidences of beats.

The corrections to the mean-time clock were determined by Mr. Chas. B. Hill.

The altazimuth at Norman was mounted on the chimney of a furnace used for preparing feed for live-stock on the ranch of Mr. N. D. Rideout.

Longitude Observations.

On the three nights on which observations were made at both stations, the following differences of longitude were obtained between the transit instrument of the Lick Observatory and the altazimuth at Norman: —

		m.	s.
1889, Feb. 16	Diff. of Longitude	2	11.04
" " 18	" " "	2	10.98
" " 19	" " "	2	11.19
	Mean	2	11.07 ± 0.05

The probable error which has been assigned is a little greater than that deduced from the discrepancy of the individual results.

Some of the other comparisons, not available for an accurate determination of longitude, give the following results: —

				m.	s.
Evening signals,	Feb.	17	(no observations)	2	11.65
Noon	"	" 17	(repeated by hand at Sacramento) . . .	2	10.70
"	"	" 18	(" " " " ") . . .	2	11.19

The error of the noon signal (the regular time signal for the railroads) is assumed to be 0.

These values have been used merely as checks on the more accurate ones given above.

Personal Equation. — From observations made on two nights after returning to Lick Observatory, it was found that C. B. Hill observed transits $0^s.11$ before J. E. Keeler, each observer using the same method as during the longitude work. The difference of longitude is to be diminished by this amount, and is, therefore:

m.	s.		s	m	s.
2	11.07	−	0.11	= 2	10.96

The longitude of the Lick Observatory transit instrument west of Greenwich is $8^h\ 6^m\ 34^s.29$, hence the longitude[1] of the altazimuth at Norman was: —

h.	m.	s.
8	8	45.25

Latitude Observations.

The latitude was determined by leaving the instrument in the meridian after the time observation, and observing the zenith distances of stars taken from the time list as they passed the middle thread. By reversing the axis during the course of the measurements, and observing the same number of stars in each position of the instrument, both north and south of the zenith, errors of the zenith point, or index correction, flexure, and refraction, were almost entirely eliminated.

[1] Subject to correction for transmission time. This is unknown, but doubtless very small, and has been neglected.

MERIDIAN ZENITH DISTANCES.

FEBRUARY 18, 1889.

Aneroid = 30.21 inches, Temperature = 32° Fahr.
or Barom. at 32° = 30.33 True refraction = mean refr. × 1.060.
Zenith point = 179° 59′ 20″.0.

Star.	Circle [East].				App. Zenith Dist.			Refrac.	ζ			δ			ϕ		
	°	′	″		°	′	″	″	°	′	″	°	′	″	°	′	″
10 Urs. Maj.	182	47	36.3	N	2	48	16.3	3.0	2	48	19.3	42	13	16.2	39	24	56.9
σ^2 Urs. Maj.	208	8	53.3	N	28	9	33.3	32.7	28	10	6.0	67	35	5.9			59.9
θ Hydrae	143	21	55.5	S	36	37	24.5	45.4	36	38	9.9	2	46	49.2			59.1
1 Draconis	222	22	25.6	N	42	23	5.6	55.6	42	14	1.2	81	49	0.0			58.8
θ Urs. Maj.	192	44	57.7	N	12	45	37.7	13.9	12	45	51.6	52	10	55.8			64.2
10 Leo. Min.	177	27	47.0	S	2	31	33.0	2.7	2	31	35.7	36	53	20.4			56.1
ε Leonis	164	51	34.5	S	15	7	45.5	16.5	15	8	2.0	24	17	1.1			63.1
μ Leonis	167	6	9.7	S	12	53	10.3	14.1	12	53	24.4	26	31	40.9			65.3
	[West.]																
π Leonis	210	49	9.9	S	30	49	49.9	36.6	30	50	26.5	8	34	29.6			56.1
α Leonis	206	53	22.2	S	26	54	2.2	31.0	16	54	33.2	12	30	28.4			61.6
λ Urs. Maj.	175	56	21.9	N	4	2	58.1	4.3	4	3	2.4	43	18	1.2			58.8
30 Urs. Maj.	153	17	13.5	N	26	42	6.5	30.7	26	42	37.2	66	7	36.1			58.9
β Leo. Min.	182	7	48.8	S	2	8	28.8	2.2	2	8	31.0	37	16	27.8			58.8
ϱ Leonis	209	31	8.9	S	29	31	48.9	34.6	29	32	23.5	9	52	33.5			57.0

The circle reading given in the second column is corrected for error of level.

FEBRUARY 20, 1889.

Aneroid = 30.195 inches, Temperature = 44° Fahr.
or Barom. at 32° = 30.315 True refraction = mean refr. × 1.034.
Zenith point = 179° 59′ 17″.6.

Star.	Circle [West].				App. Zenith Dist.			Refrac.	ζ			δ			ϕ		
	°	′	″		°	′	″	″	°	′	″	°	′	″	°	′	″
ε Gemin.	194	9	39.8	S	14	10	22.2	15.1	14	10	37.3	25	14	22.5	39	24	59.8
ζ Gemin.	198	40	3.7	S	18	40	46.1	20.2	18	41	6.3	20	43	52.9			59.2
λ Gemin.	202	39	35.7	S	22	40	18.1	24.9	22	40	43.0	16	44	19.1			62.1
ι Gemin.	191	23	3.7	S	11	23	46.1	12.2	11	23	58.3	28	1	2.7			61.0
α^2 Gemin.	187	16	19.8	S	7	17	2.2	8.2	7	17	10.4	32	7	51.0			61.4
	[East.]																
β Gemin.	168	32	4.5	S	11	7	13.1	11.8	11	7	24.9	28	17	34.8			59.7
φ Gemin.	167	37	36.3	S	12	21	41.3	13.1	12	21	54.4	27	3	6.3			60.7
χ Gemin.	168	40	43.4	S	11	18	34.2	12.0	11	18	46.2	28	6	15.3			61.5
27 Lyncis	192	23	40.2	N	12	24	22.6	13.4	12	24	36.0	51	49	35.5			59.5
β Cancri	150	6	21.1	S	29	52	56.5	34.2	29	53	30.7	9	31	31.2			61.9

The circle reading given in the second column is corrected for error of level.

Other Latitude Observations. — On February 18, the zenith distance of Polaris was observed, when about two hours from lower culmination, the resulting latitude being 39° 24′ 57″.6.

On February 20, δ Urs. Min., S. P., was observed near the meridian, giving latitude 39° 24′ 56″.2.

Giving each of these weight 1, the mean of all (26 observations) is

$$\varphi = 39^\circ\ 24'\ 59''.8 \pm 0''.3$$

The longitude is

$$\lambda = 8^h\ 8^m\ 45^s.25 \pm 0^s.05$$

This is the position of the instrument.

The station occupied by Professor Pritchett was 195 feet distant from the altazimuth, in the direction S. 57° 43′ W. It was therefore 104 feet = 1″.03 South and 165 feet = 0ˢ.140 West. Hence the position of this station was

$$\varphi = 39^\circ\ 24'\ 58''.8 \pm 0''.3$$
$$\lambda = 8^h\ 8^m\ 45^s.39 \pm 0^s.05.$$

J. E. KEELER.

LICK OBSERVATORY,
Mt. Hamilton, Cal.

LIBRARY OF THE UNIVERSITY OF CALIFORNIA

THE original negatives of the expedition remain in the possession of the Observatory of Washington University, and will be cheerfully loaned to any one desiring to make an original study of the corona or for purposes of comparison with other photographs.

NEGATIVE NO. 1.

This negative was taken immediately after the beginning of totality, the time of exposure being approximately 0.5 *second. The negative is very sharp and distinct, the polar filaments being a prominent feature. The corona is shown to a distance of three fourths of a diameter from the sun's disc. The lower edge of this plate represents a horizontal line which is inclined at an angle of* 20° 12′.3 *to a parallel of declination.*

NEGATIVE NO. 1.

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NEGATIVE NO. 2.

The time of exposure was 3.0 *seconds. The polar filaments are strongly marked. A bend in the coronal matter north preceding the sun shows with great distinctness. The corona is visible to more than a diameter. The lower edge of this plate represents a horizontal line which is inclined at an angle of* 20° 12′.3 *to a parallel of declination.*

NEGATIVE NO. 2.

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NEGATIVE NO. 3.

This negative had an exposure of a little over six seconds, and was the first one developed. The polar filaments are shown quite plainly, extending to distances of from a half to three quarters of a diameter from the sun. The bend in the coronal streamers on the north preceding limb of the sun is a marked feature of this negative.

The equatorial streamers can be traced to a distance of about one and a half diameters of the sun. A curious diffraction effect is shown in the centre of the image of the moon.

Two large prominences are shown on the western limb, and five are shown on the eastern limb, two of the latter being quite faint. The lower edge of this plate represents a horizontal line which is inclined at an angle of 20° 12′.3 *to a parallel of declination.*

NEGATIVE NO. 3.

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NEGATIVE NO. 5.

This negative had an exposure of nearly twenty-eight seconds, and shows traces of the corona at a distance of over two diameters from the sun's disc. The moon's motion is quite appreciable during the interval, and its effect is noticeable in the reproduction of this negative. The lower edge of this plate represents a horizontal line which is inclined at an angle of 20° 12′.3 *to a parallel of declination.*

NEGATIVE NO. 5.

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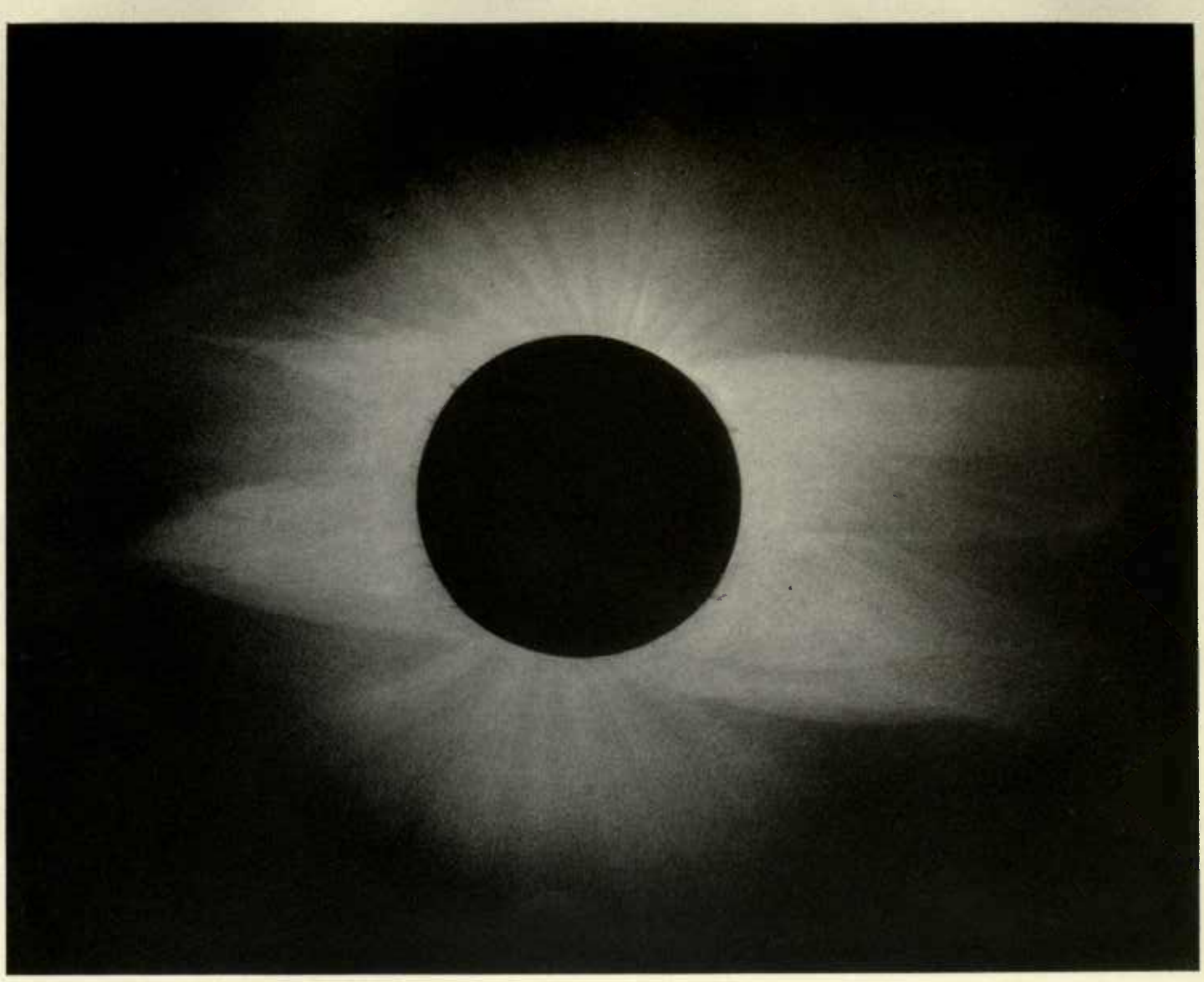
REPRODUCTION FROM ALL THE NEGATIVES.

This reproduction of the corona is the result of a most careful study of all the negatives. The method employed is completely described by Professor Engler in his report. It represents completely and with great accuracy the collected evidence of all the negatives. The lower edge of the plate represents a horizontal line which is inclined at an angle of 20° 12′.3 *to a parallel of declination.*



REPRODUCTION FROM ALL THE NEGATIVES.

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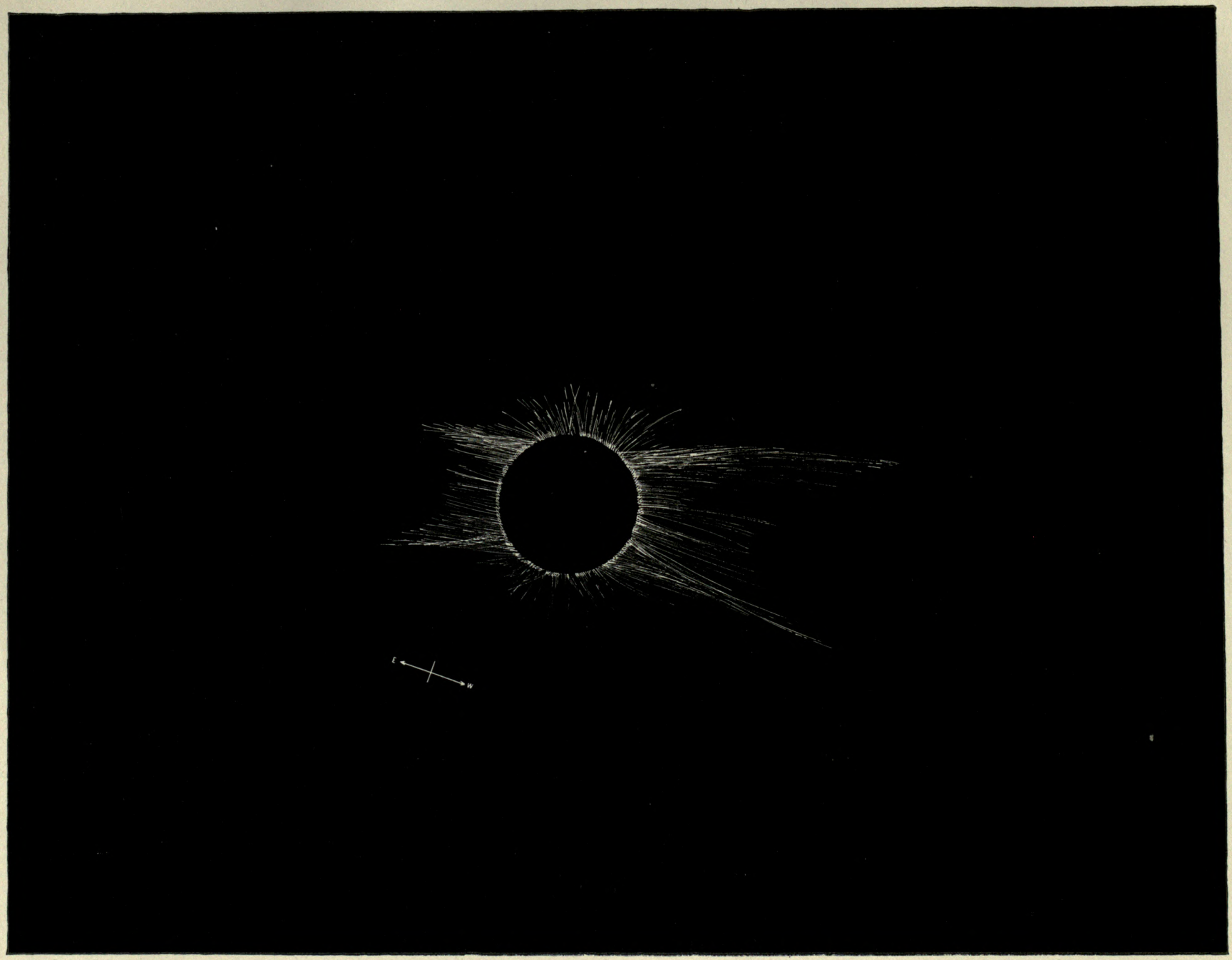
DRAWING OF THE CORONA. — PROFESSOR ENGLER.

The sketch of the corona on the opposite page is a photo-engraving of a pencil drawing made by Professor Engler during the two minutes immediately following totality.



DRAWING OF THE CORONA—PROFESSOR ENGLER.

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DRAWING OF CORONAL STREAMERS. — SEÑOR VALLE.

The sketch of the coronal streamers on the opposite page is a photo-engraving of a pencil drawing by Señor Valle who used a disc to shut out the inner corona. The black circle in the centre is not the moon but this disc, which had an angular diameter of 68′.

DRAWING OF CORONAL STREAMERS—SEÑOR VALLE.

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